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Electrostatic Imaging of Charges Liberated in Dielectric Liquids by Ionizing Radiation*

G. Charpak
CERN-EP
Geneva, Switzerland

and

D.F. Anderson and B.J. Kross
Particle Detector Group
Fermi National Accelerator Laboratory
Batavia, IL 60510 USA

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Abstract

The charge liberated by beta particles in a liquid argon-methane mixture has been collected on a mylar film and the image developed with a technique similar to electrophotography. The image of the beta-emitting lines on a chromatographic gel have also been produced in this way.

Introduction

Within the framework of a continuing effort to image the trajectories of charged particles in dielectric media [1,2], we have tested the possibility of collecting charges liberated in liquid argon (LAr) on an insulating surface. The image is then developed with a technique similar to electrophotography.

The ultimate goal is to obtain the projected image of the tracks of minimum ionizing particles in a liquid. This requires read-out methods with a sensitivity not available at present and thus a research effort is being pursued. It seems of interest to us to verify that charges liberated by ionizing radiation in LAr can be collected on a mylar sheet and imaged with presently available methods, since this technique may also find applications in other fields where the imaging of radioactive sources is of interest.

Experimental Procedure

A schematic of the experimental setup is shown in fig.1. A radioactive source is separated from a 125 μm thick mylar sheet by a 2 mm gap filled with a mixture of LAr and methane. The back side of the mylar sheet has a conductive layer of indium tin oxide (ITO) deposited on it. This conductive layer is in contact with the positive high-voltage electrode with the source held at ground potential. Before installation, the mylar was first washed with ethanol to remove any charge from the surface.

We conducted a preliminary study, with beta- and alpha-emitting sources. The image of the collected charges was developed with a liquid toner which is used in electrophotography [3]. Our experiments were conducted with the most sensitive toner that we could find. The toner (CR42A) was produced by Coulter Systems Corp., Bedford, Mass. and kindly put at our disposal by the firm. It is made of a dispersion of particles of a median size of 0.2 μm, which are positively charged, and dispersed in an insulating liquid. With this toner we were able to observe images when the surface potential reached about 25 V.

In order to produce an image of the charge liberated in the LAr, the charge was collected on the mylar sheet for times that varied from a few minutes to several days, depending on the intensity of the source. After completion of the charge collection, the LAr/methane was removed and the mylar brought to room temperature to avoid the condensation of moisture. The mylar was then immersed in the toner for a few seconds

and then washed by gentle agitation in kerosene. During the warm-up period the voltage had to be left on the cell in order to prevent loss of charge.

Results

It was found early on that the quality of the image could be improved by the addition of a few per cent methane. This was due to a reduction in the diffusion of the electrons. We also found that the results were somewhat improved by an increase in the collection field used, particularly with the LAr/methane mix. Most of our work was done with a collection field of 1250 V/mm.

One object of our effort was to image the beta-emitting lines on a chromatographic gel carrying proteins labeled with ^{35}S. After an exposure of 12 hours, the image in Fig. 2a was obtained. Figure 2b is an image produced by exposing the gel to a special autoradiography film for 6 hours. The distance between the three lines to the right of the two darkest lines is about 400 μm, with a width of about 120 μm. The width of the lower strip of gel is about 6.6 mm. We obtained the correct pattern of lines, showing that our experimental procedure does not destroy the images, but the spatial resolution is clearly degraded.

Discussion

The sensitivity of the toner is far below what is required for the imaging of minimum ionizing particles in LAr. If we assume that the track left by such a particle in LAr had a width of 20 μm after 1 cm of drift, we would have a voltage of about 4 mV at the surface of the 125 μm mylar sheet. For a heavy relativistic ion, the charge density is about 8000 times larger. When recombination in the LAr is taken into account, this heavy ion would yield a surface potential of about 3 V on the surface of the mylar. This is still below the sensitivity of the toner.

However, our observations may prove to be of interest for applications where the acceptable level of sensitivity can be much lower. For instance, the spatial distribution of the beta-emitters is of primary importance in a field of research such as biology. A research effort has been invested in studying the possibility of replacing the photographic emulsions used for autoradiography, which suffer several defects: low sensitivity, lack of linearity, and small dynamic range.

Gaseous detectors have also been widely studied. Their major drawback is the large range of the emitted electrons in the gas. This gives them a resolution of 1 mm in the best cases, and more often, several millimeters.

The range of the emitted electrons is about three orders of magnitude smaller in LAr, which could be a great advantage if one could measure the collected charge with sufficient sensitivity and accuracy. At present, experiments ongoing at Ecole de Physique et Chimie in Paris, and at CERN, indicate that sensitivities at least ten times better than the present toner can be obtained and that further substantial improvements in sensitivity can be reasonably expected.

We have shown that LAr can be used as a detection medium for the imaging of ionizing radiation. It would be of interest to perform this research with warm liquids, such as 2,2,4,4-TMP, though the problems of high purity requirements for the warm liquids may make it impractical.

Acknowledgment

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Figure Captions

Figure 1 Schematic of experimental setup.

Figure 2 a) Image produced on mylar film by beta-emitting lines on a chromotographic gel , and b) image produced with autoradiography film.

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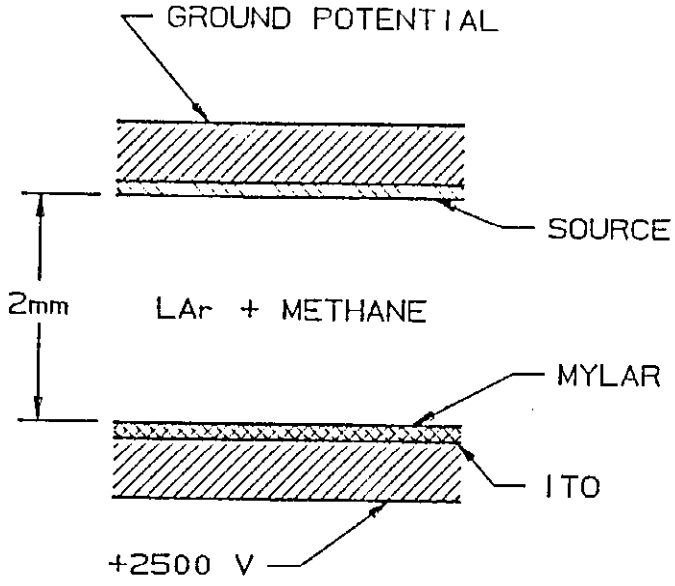

Figure 1

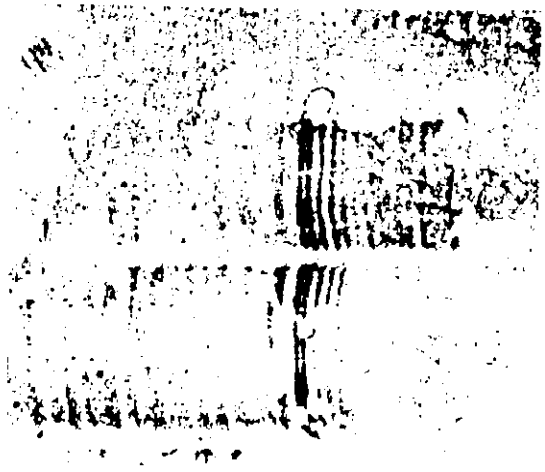

Figure 2a

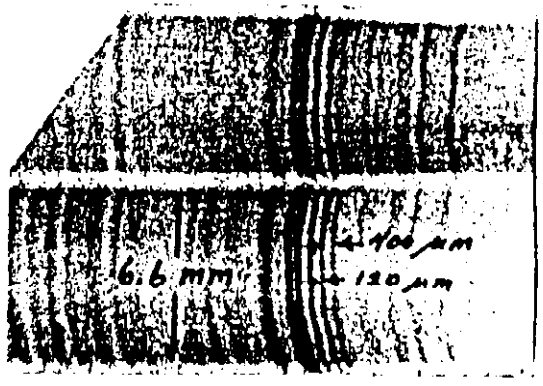

Figure 2b